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ABSTRACT

Four classes of high school chemistry students (N=108) were randomly assigned to experimental and control groups to investigate the effectiveness of a computer assisted instruction (CAI) package during a unit on writing/naming of chemical formulas and balancing equations. Students in the experimental group received drill, review, and reinforcement using the microcomputer while students in the control group used conventional paper-and-pencil worksheets for their lessons. Findings show: (1) that the use of the microcomputer materials did not contribute to more effective learning (the control group's scores were significantly higher on an achievement test than the CAI group mean); (2) that there were no significant interactions favoring either CAI or control activity for students of differing cognitive levels (as measured by Lawson's Classroom Test of Formal Operations); (3) that females displayed attitudes toward computers that were nearly identical regardless of treatment; that males' attitudes were far more favorable toward computers in the CAI group (especially favorable were males' attitudes toward the use of CAI in chemistry instruction); and (4) that females' attitudes toward chemistry were more favorable in the control group while males' attitudes toward chemistry were essentially the same between experimental and control groups. The attitude survey used in the study, along with an analysis of student errors and a bibliography, are appended. (Author/JN)

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THE EFFECTIVENESS OF A COMPUTER-ASSISTED INSTRUCTION PACKAGE IN SUPPLEMENTING TEACHING OF SELECTED CONCEPTS IN HIGH SCHOOL CHEMISTRY: WRITING FORMULAS AND BALANCING CHEMICAL EQUATIONS

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THE EFFECTIVENESS OF A COMPUTER-ASSISTED INSTRUCTION PACKAGE IN SUPPLEMENTING TEACHING OF SELECTED CONCEPTS IN HIGH SCHOOL CHEMISTRY: WRITING FORMULAS AND BALANCING CHEMICAL EQUATIONS

Camille L. Wainwright

Introduction

During the past two decades, applications of computers have infiltrated all levels and areas of education, just as computers have invaded homes, offices, laboratories and businesses. "Educators, like everyone else, have had visions of using these machines for making their jobs easier and for improving their product: educated children" (Wiebe, 1983). As instructional applications have developed, numerous research studies have evolved, in which attempts have been made to determine the effectiveness of this new medium in terms of student affect and achievement. In looking specifically at studies in which computer-assisted instruction (CAI) has been used in chemistry education, numerous examples exist in which the computer instruction has served to enhance achievement (Castleberry, Culp & Lagowski, 1973, Grandey, 1971, Culp & Castleberry, 1971, and Castleberry, Montague, & Lagowski, 1970). In several studies, CAI

has also been shown to promote favorable attitudes toward computers, chemistry and/or the course itself (Summerlin, 1973, Culp & Castleberry, 1971, Castleberry, Montague, & Lagowski, 1970). Summerlin, however, reported a study using a randomized sample in which the control group (traditional instruction) scored significantly higher on immediate and delayed posttests on chemistry achievement than did the CAI group (Summerlin, 1971).

Two recent meta-analyses have examined the research literature on computer-assisted instruction specifically in science education. Willett and Yamashita (1983), found a gain on achievement score measures (mean effect size of +0.13) as a result of the use of CAI. Wise and Okey (1983) found that students using personal computers enjoyed significantly higher course averages, improved performance, and positive attitudes toward the use of computers in their coursework. These authors reflected on the small number of studies that had been published in which CAI had had adverse affects on achievement; they doubted that investigators were looking for negative effects (Wise & Okey, 1983).

Richard Clark has suggested, however, that the various meta-analyses have provided misleading information. He concludes that the media comparison studies have shown that "media do not influence learning under any conditions" (Clark, 1983). The instructional medium chosen is merely the delivery system for the

instructional design. Too often media comparison studies have suffered from confounding effects, usually due to uncontrolled variables in either the content presented or the instructional strategy. Clark suggests that it is not surprising that current research studies show favorable results for CAI, since historically, media comparison research has tended to produce positive effects for whichever is the latest technological innovation. Too little attention has been paid to inherent attributes of various media, along with the optimal instructional strategies for utilizing those attributes (Clark, 1983).

A subject of major concern among chemistry educators in recent years has been the relationship between the student's cognitive development level and ability to acquire an understanding of chemical concepts (Good, Kromhout & Mellon, 1979). Herron has suggested that chemistry courses are generally taught at a level of abstraction requiring formal thought, even though the majority of students have not yet attained a formal operations level of cognitive development. "Chemistry is formal by its very nature" (Herron, 1975). Nevertheless, Herron advises educators that a substantial amount of chemistry theory can be presented in such a way that even students at a concrete operational level can comprehend the concepts, especially if instruction relies heavily on exploration, manipulation and interaction (Herron, 1975). Finley has reported on a study which

was designed to identify the specific topics within the science discipline areas (biology, chemistry, and physics) which are felt by science teachers to be the most important in each content area, as well as those which are considered to be the most difficult. Questionnaire responses from chemistry teachers rated "writing chemical formulas" and "balancing chemical equations" as the two most important concepts in teaching high school chemistry. Significantly, both of these concepts were also rated among the fifteen most difficult for students to learn (Finley, Stewart & Yarroch, 1982).

Niaz and Lawson propose that learning to balance chemical equations using the standard trial-and-error method requires formal reasoning and places demands on working memory capacity (Niaz & Lawson, 1985). However, Shayer suggests that early formal thinkers can understand "the conservation of elements in an exchange reaction", and "can balance and use chemical equations, provided that plenty of drill is given" (Shayer & Adey, 1981).

Perhaps the drill provided via computer-assisted instruction can be shown to be differentially effective, as measured among varying ability levels. Several investigators have suggested that computers in education may provide their greatest potential for disadvantaged students, those of low ability, and the concrete operational students (Kulik, Bangert & Williams, 1983; Cavin & Lagowski, 1978; Jamison, Suppes & Welles, 1974). Others have

suggested that affective outcomes, such as attitude toward CAI in science education, may be gender-related (Cavin, Cavin & Lagowski, 1981). Both achievement and attitude differences will be analyzed in relation to gender and cognitive ability as a result of CAI in selected chemistry concepts.

Purpose

This study is an empirical research design which was developed in order to answer the following questions:

1. In supplementing traditional instruction on selected chemistry topics, do the attributes of the microcomputer materials contribute to effective learning as measured by an achievement test?
2. Among chemistry students of differing levels of cognitive development, is computer-assisted instruction an effective supplement to traditional instruction?
3. As a result of using computer-assisted instruction in a high school chemistry course, do students have a more positive attitude toward computers and chemistry?

Method

Four general chemistry classes in a suburban high school were randomly assigned to two treatment groups, experimental and control (N = 108). For a period of study of chemical formulas and equations (three weeks), the experimental group used specific microcomputer software, while the control group used traditional worksheets (containing identical activities) for daily exercises. One major purpose of the study was to conduct empirical research on instructional materials within the normal school environment. In order to minimize classroom disruption, the normal classroom routine was continued as much as possible. Teachers presented concepts, assigned text readings and arranged laboratory investigations identically for both treatment groups. The differences were only in the method of skill reinforcement in the selected concepts--whether by computer, or by paper-and-pencil worksheets. The two teachers involved in the study are of the same gender, had taught and developed materials together for two decades, and have a similar style of concept presentation.

In order to determine the effectiveness of two different instructional techniques (CAI and Control), the Posttest-Only Control Group Design was selected (Campbell & Stanley, 1963). Following the period of study, all students completed an achievement test and an attitude survey. In order to determine

differential effects due to cognitive development level, a pretest had been utilized to measure formal reasoning skills.

Prior to the main study, a small sample of students from the same school system participated in a pilot study, in order to ascertain approximate time requirements for segments of the computer program, and to determine problem areas. All students in the main study (treatment and control) had opportunities to use chemistry CAI materials (unrelated to the selected concepts) prior to the commencement of this project, in order to familiarize them with the computer and to eliminate potential effects of novelty.

Materials and Instruments

Computer Software:

The microcomputer software used for the computer activity is General Chemistry , distributed by COMPress, Inc. (Smith, Chabay, Kean, 1983). For the main study, Disks 2 and 3 were used ("Nomenclature" and "Chemical Formulas and Equations"). The students had available at each microcomputer a set of instructions for using the computer, a periodic table of the elements, and a list of common ions. Students in the control group were provided with worksheets which had been generated from trial runs of the software in order to be certain that the content was parallel.

Having controlled for content as well as teacher and

contextual variables, the only remaining uncontrolled variables are those differences between worksheet and computer activities, due to the attributes of the microcomputer. Further analysis indicates these to be the differences:

1) The software program `freezes' the product and reactant formulas (including subscripts) in sections on balancing equations while students using worksheets are free to make the two most common errors--changing subscripts and chemical species--to make the equation balance (Schug, 1977).

2) Students using the microcomputer were given immediate feedback on errors, whether they involved improper subscripts, spelling errors, or unbalanced equations; the software requires, in fact, a correct answer in order to proceed, and provides prompts following the second error. Students in the control group had feedback available, too, although not as immediate nor continuous. The teacher circulated in the room while students completed worksheet exercises, in order to provide assistance. Worksheets were corrected and scored when all students in the class had finished.

Classroom Test of Cognitive Development:

Prior to the empirical study, the Classroom Test of Cognitive Development (Lawson, 1978) was administered to all students enrolled in introductory chemistry in the high school. The 15-item test is patterned after traditional Piagetian tasks for determining reasoning ability (Inhelder & Piaget, 1958). It is presented as a series of demonstrations to an entire class at one time, and scored rather easily. Both the answer and statement of reasoning must be correct in order to score a point on an item. The test scores are used to determine students' reasoning patterns along a continuum: concrete reasoning (0-5), transitional (6-10), formal reasoning (12-15). Classroom test statistics for this test have been previously published; reliability of the test (KR-20) was reported as 0.78 (Lawson, 1978). Since the results of this test indicated that the majority of students were in the formal stage (62.5% formal, 33.7% transitional, 3.8% concrete), the two classifications `concrete' and `transitional' were combined into one stage--`non-formal', in an effort to balance cell frequencies.

Achievement Test:

Following completion of the unit of study, a twenty-five item multiple-choice test was administered to students in the experimental and control groups. Questions were developed from a list of instructional objectives on which the computer software program was based, and were closely related to both the software and worksheet exercises. The achievement test had been administered to a pilot study group of fifty students, and had been modified in order to be certain that questions had a reasonable level of difficulty and appropriate distractors.

Using SPSS (Nie, et al, 1975), the reliability coefficient for this instrument was determined to be 0.762. A panel of six experts examined the instrument for validity, to be certain that items were a true test of the associated instructional objectives. One indicator of convergent validity is the significant correlation between the achievement test scores and PSAT Math scores ($r = 0.543$) as well as GPA ($r = 0.664$). Studies have indicated that these two measures, PSAT Math and GPA, are highly correlated with achievement in chemistry (Wiseman, 1981), so that a significant correlation can provide some assurance of convergent validity (Marshall & Hales, 1972; Ozsogomonyan & Loftus, 1979).

Attitude Survey:

Following the experimental treatment and immediately after completing the achievement posttest, students were asked to complete an attitude survey containing nineteen Likert-type items (Appendix A). Items had been developed after a study of research articles on attitude surveys (e.g. Shrigley, 1983), or selected from existing attitude surveys (MECC, 1979). Reliability of the Attitude Survey was established using SPSS (Nie, et al, 1975); the reliability coefficient for the survey, including all nineteen items, was 0.801.

The Attitude Survey was subjected to a principal components analysis; this analysis extracts only components with eigenvalues greater than one and uses the varimax method of axes rotation (Kaiser, 1960). The results of this analysis verified the existence of two main subscales within the total instrument; the two subscales with their reliability coefficients are 1) Attitudes Toward Chemistry (0.808) and 2) Attitudes Toward Computers (0.840). Shrigley indicates that high item-total coefficients (at least 0.30) indicate evaluative discrimination (Shrigley, 1983); mean item-total correlation coefficent, for the nineteen items was 0.38. Attitude Toward Chemistry included items #1, 5, 6, 10, 11, 13, 17, and 19. Attitude Toward Computers consisted of items #2, 3, 4, 7, 8, 9, 12, 14, 15, 16, and 18.

Items which had reversed values in scoring were #1, 3, 10, 13, 16, and 18.

Other Instruments:

Attached to the Attitude Survey were an additional five questions of a personal or demographic nature (Appendix A). These items were later used in correlation studies.

Midway through the experimental period a sample of students were given a brief written test on writing and naming formulas. Since this was open style rather than multiple-choice, the answers were analyzed in order to detect specific types of errors within eight categories (Appendix B).

Findings and Discussion

Question 1: In supplementing traditional instruction on selected chemistry topics, do the attributes of the microcomputer materials contribute to effective learning as measured by an achievement test?

In spite of numerous studies in which CAI was effective in producing achievement gains, in this study the use of the microcomputer materials by the experimental group clearly did not contribute to more effective learning of concepts. Tables 1 and 2 provide analysis of the achievement test scores by treatment and

by hour of the day. The control group students' scores are significantly higher on the achievement measure. Since period of the day is also a significant factor, it is included as a separate main effect in subsequent analyses.

Question #2: Among chemistry students of differing levels of cognitive development, is CAI an effective supplement to traditional instruction?

Based on suggestions in the research literature that CAI may be more effective for students of low cognitive development levels, achievement scores were analyzed between treatment groups on the basis of cognitive development level. One might hypothesize that non-formal students in the experimental group (CAI) would score higher on the achievement test than those in the control group, while formal students in the control group might have scored significantly higher than those using CAI. However, no such differential results were found based on development level.

A three-way analysis of variance was used to investigate the relationship between achievement test scores and treatment (Tables 3 and 4). Development stage is, of course, a significant main effect, with students in the formal development stage scoring significantly higher on the achievement test. Some loss of sample occurred in this analysis because of students who had been absent

when the Lawson's test was administered.

Question #3: As a result of using CAI in a high school chemistry course, do students have a more positive attitude toward computers and chemistry?

In measuring attitudes toward computers, differential treatment effects were discovered between males and females as indicated by a significant interaction between treatment and gender (Tables 5 and 6). Females displayed attitudes toward computers that were nearly identical whether in the control or experimental groups. Males' attitudes, however, were far more favorable toward computers in the CAI group. The analysis of variance indicated no significant main effect due to period of the day, but provided the confounding effect of an interaction between gender and hour (Figures 1 and 2).

Analysis of the same attitude scale (Computers) by cognitive development level provided no differential results (Table 7 and 8). Among the main effects (treatment, development level and hour), only treatment means are significantly different ($p < 0.001$), with no significant interactions.

The analysis of attitudes toward chemistry was also conducted; significant interactions were measured between treatment and gender, but also between treatment and hour (Tables 9 and 10). Females exhibited a much more favorable attitude

toward chemistry in the control group than in the CAI group regardless of the period, while attitudes among males were nearly the same in botn treatment conditions (Figures 3 and 4).

Analysis of attitude toward chemistry indicated a significant difference between development levels, with formal students having a more positive attitude toward chemistry than non-formal students (Tables 11 and 12). There was no interaction between development stage and treatment on attitude toward chemistry.

Other Results:

Mid-way through the experiment, part of the sample was administered a brief test on writing and naming formulas. The results of this test were analyzed in two ways. First, total scores (number of correct answers) were determined for each student. Second, the types of errors were tallied for all students, within error categories (Appendix B). In each error category, the experimental group (CAI) scores were higher (more mistakes), although they were significantly higher ($p < 0.05$) in only three of the eight categories (#1, 6 and 8).

In order to have a clearer understanding of the student population, demographic and background data had been obtained and analyzed. Table 13 provides correlation data on eleven variables with achievement test, attitude toward chemistry and attitude toward computers. Although few background variables provided

significant correlations, some are of interest. Typing ability, for example, was significantly correlated with attitudes toward both computers and chemistry. And prediction of a high grade in chemistry class was a strong correlate with achievement.

Conclusions and Implications

In spite of numerous studies in which CAI treatments in chemistry have resulted in higher achievement, this investigation has suggested that the traditional worksheet approach is more effective than CAI, even when using a software package respected by educators for its instructional design. Identification of the specific reasons for thiese results is difficult. Although the attributes of the computer software in this study (immediate feedback, response-checking, and error avoidance) were felt to be potentially useful in instruction of selected concepts in chemistry, this was not the case. One additional difference between the two treatments, was the fact that more directions were necessary in order to operate the computer and work through the lessons, than are required to complete a worksheet. Perhaps the inability to learn the concepts effectively using the computer was due to the "excessive information-load demand" in working memory (Wollman, 1982) rather than inherent superiority of worksheets

over the CAI method.

Molnar has suggested that motivated students will learn from any medium, properly use (1982). The measure of females' attitudes toward chemistry in the CAI groups was quite unfavorable, suggesting that they were not highly motivated toward learning chemistry through the use of CAI, which may have contributed toward poor achievement. Males' attitudes toward chemistry were not significantly different between treatment groups; however, males' attitudes toward computers were much higher in the CAI group. Perhaps the male students tended to concentrate on the enjoyment of the use of the computer during chemistry class more than on acquiring the chemistry concepts.

In the analysis of attitude scales by treatment and development level, students who had used computers extensively (the CAI group) had a more positive attitude toward computers, but no interactions due to development level were found. However, in analyzing attitude toward chemistry, the development factor was significant; students with formal reasoning ability felt better about the course.

Further research with larger samples might be able to overcome the confounding effects of scheduling; period of the day became a significant factor in this study and made it difficult to analyze other issues. The error analysis scheme (Appendix B) provided insight into comparisons of errors committed by the two

treatment groups on writing and naming formulas. This method was not applied, however, to balancing equations, because of the type of achievement test used (multiple-choice). With a free-response type of test and detailed error analysis, perhaps a clearer understanding could be achieved as to the success of traditional instruction over CAI in this topic.

In spite of numerous studies in which CAI was the favored instructional method, this study suggests caution in adopting the general assumption that CAI is more successful than traditional methods. In the majority of studies in which CAI was favored, subjects were volunteers rather than randomly assigned, and often used CAI as remedial or supplemental instruction, beyond that which the control group received. These, in fact, may be optimum applications for CAI, rather than required, whole-group instruction such as in this study. The need for further inquiry is indicated in the search for proven effective applications of CAI in science education.

Table 1

Means and Standard Deviations for the Achievement Test Scores in Each Treatment Group by Period of the Day

	Control			CAI		
Period	Mean	SD	N	Mean	SD	N
1	19.407	3.489	27	16.583	3.752	24
2	19.923	4.127	26	19.417	4.149	24

Table 2

Summary of Two-Way Analysis of Variance on Achievement Test Scores

Source of Var.	Sum of Sq.	DF	Mean Sq.	F	Sign. of F
Main Effects	139.202	2	69.601	4.618	.012
Treatment	69.836	1	69.836	4.633	.034
Hour	70.614	1	70.614	4.685	.033
Two-Way Interaction					
Treatment/Hour	33.819	1	33.819	2.244	.137
Explained	169.295	3	56.432	3.744	.014
Residual	1462.031	97	15.072		
Total	1631.327	100	16.313		

Table 3

Means and Standard Deviations for the Achievement Test Scores in Each Treatment Group by Period and by Development Stage

		Control			CAI		
Period	Stage	Mean	SD	N	Mean	SD	N
1	Non-Formal	18.222	3.768	9	14.417	3.919	12
	Formal	20.471	2.700	17	18.818	2.040	11
2	Non-Formal	17.286	5.469	7	17.667	5.613	9
	Formal	20.647	3.239	17	20.467	2.669	15

Table 4

Summary of Three-Way Analysis of Variance on Achievement Test Scores

Source of Var.	Sum of Sq.	DF	Mean Sq.	F	Sign. of F
Main Effects	337.908	3	112.636	8.798	.001
Treatment	38.196	1	38.196	2.984	.088
Dev. Stage	226.810	1	226.810	17.717	.001
Hour	23.668	1	23.668	1.849	.117
Two-Way Interactions					
Treatment/Stage	3.502	1	3.502	.274	.602
Treatment/Hour	44.247	1	44.247	3.456	.066
Stage/Hour	.330	1	.330	.026	.873
Three-Way Interactions					
Treatmt./Stage/Hr.	10.183	1	10.183	.795	.375
Explained	407.870	7	58.267	4.551	.001
Residual	1139.388	89	12.802		
Total	1547.258	96	16.117		

Table 5

Means and Standard Deviations on Attitudes Toward Computers in Each Treatment Group by Period and by Gender

		Control			CAI		
Period	Gender	Mean	SD	N	Mean	SD	N
1	Female	41.000	7.106	9	40.455	3.725	11
	Male	39.769	7.120	13	45.222	4.631	9
2	Female	42.091	4.743	11	44.417	3.965	12
	Male	34.000	6.928	10	42.333	3.393	12

Table 6

Summary of Three-Way Analysis of Variance on Attitudes Toward Computers

Source of Var.	Sum of Sq.	DF	Mean Sq.	F	Sign. of F
Main Effects	409.998	3	136.666	4.737	.004
Treatment	324.117	1	324.117	11.235	.001
Gender	58.925	1	58.925	2.043	.157
Hour	17.384	1	17.384	.603	.440
Two-Way Interactions					
Treatmt/Gender	192.802	1	192.802	6.683	.012
Treatment/Hour	44.247	1	44.247	1.534	.219
Gender/Hour	251.455	1	251.455	8.716	.004
Three-Way Interactions					
Treatmt/Gender/Hr	.000	1	.000	.000	.998
Explained	845.331	7	120.762	4.186	.001
Residual	2279.083	79	28.849		
Total	3124.414	86	36.330		

Figure 1

Attitude Toward Computers by Gender and Treatment

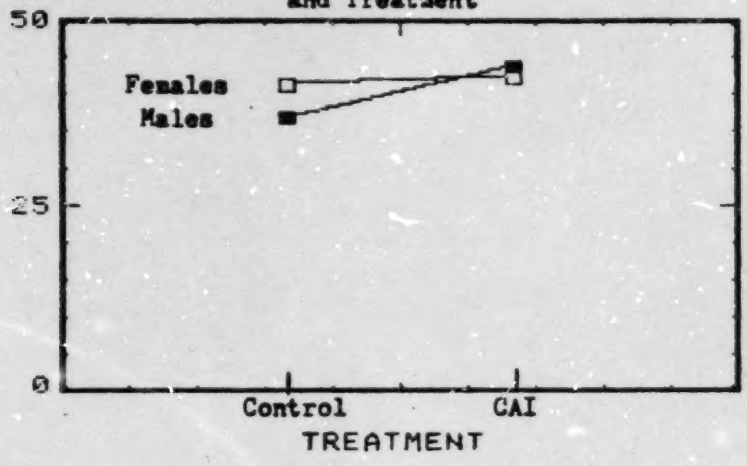

Figure 2

Attitude Toward Computers by Gender and Period of Day

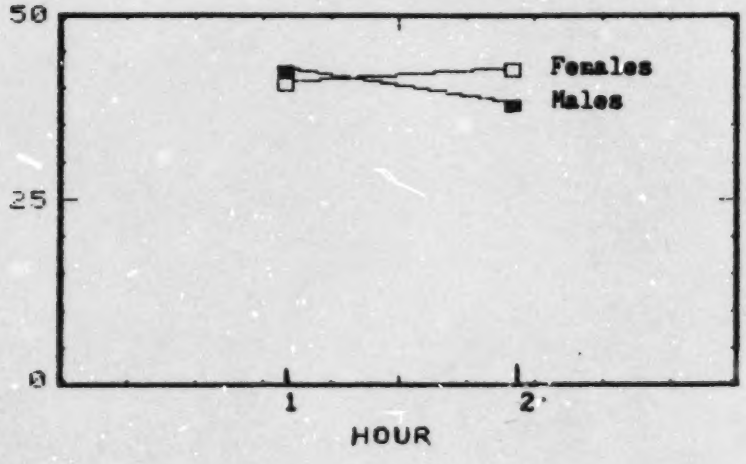

Table 7

Means and Standard Deviations on Attitudes Toward Computers in Each Treatment Group by Period and by Development Stage

		Control			CAI		
Period	Stage	Mean	SD	N	Mean	SD	N
1	Non-Formal	38.857	8.315	9	45.000	4.796	9
	Formal	40.933	6.464	15	40.800	3.967	10
2	Non-Formal	38.333	8.386	3	42.000	3.571	9
	Formal	37.812	7.459	16	44.200	3.746	15

Table 8

Summary of Three-Way Analysis of Variance on Attitude Toward Computers

Source of Var.	Sum of Sq.	DF	Mean Sq.	F	Sign. of F
Main Effects	289.187	3	96.396	2.819	.045
Treatment	259.536	1	259.536	7.590	.007
Dev. Stage	.199	1	.199	.006	.939
Hour	10.589	1	10.589	.310	.580
Two-Way Interactions					
Treatment/Stage	12.714	1	12.714	.372	.544
Treatment/Hour	16.454	1	16.454	.481	.490
Stage/Hour	14.546	1	14.546	.425	.516
Three-Way Interactions					
Treatmt./Stage/Hr	81.415	1	81.415	2.381	.127
Explained	520.058	7	74.294	2.173	.046
Residual	2598.895	76	34.196		
Total	3118.952	83	37.578		

Table 9

Means and Standard Deviations on Attitudes Toward Chemistry in Each Treatment Group by Period and by Gender

		Control			CAI		
Period	Gender	Mean	SD	N	Mean	SD	N
1	Female	28.222	5.263	9	20.091	5.873	11
	Male	25.308	3.568	13	23.556	3.127	9
2	Female	24.818	6.080	11	23.333	6.485	12
	Male	25.571	4.620	13	26.000	4.369	12

Table 10

Summary of Three-Way Analysis of Variance on Attitudes Toward Chemistry

Source of Var.	Sum of Sq.	DF	Mean Sq.	F	Sign. of F
Main Effects	211.134	3	70.378	2.759	.047
Treatment	166.437	1	166.437	6.525	.012
Gender	21.919	1	21.919	.859	.357
Hour	9.019	1	9.019	.354	.554
Two-Way Interactions					
Treatmt/Gender	95.635	1	95.635	3.749	.050
Treatment/Hour	108.362	1	108.362	4.248	.042
Gender/Hour	11.453	1	11.453	.449	.505
Three-Way Interactions					
Treatmt/Gender/Hr	27.735	1	27.735	1.087	.300
Explained	414.571	7	59.224	2.322	.033
Residual	2117.188	83	25.508		
Total	2531.758	90	28.131		

Figure 3

Attitude Toward Chemistry by Gender

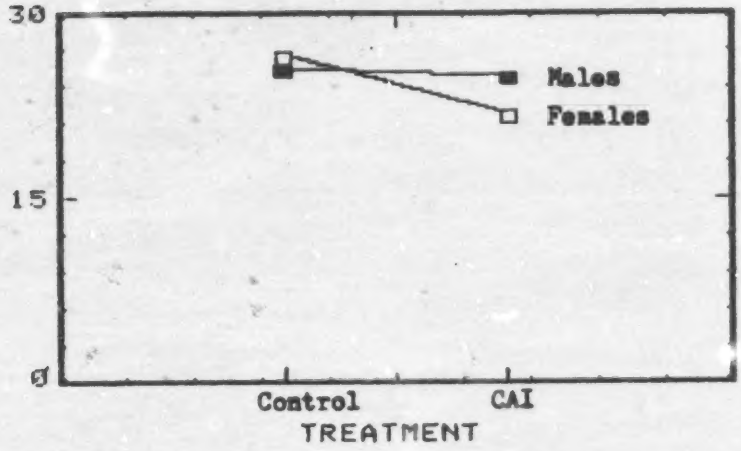

Figure 4

Attitude Toward Chemistry by Hour

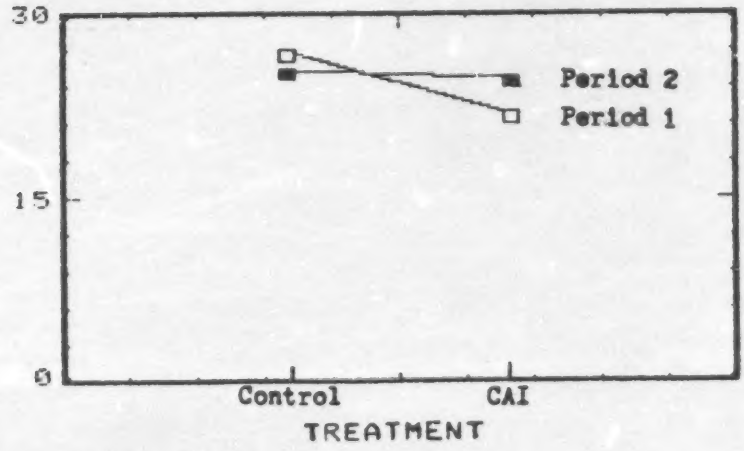

Table 11

Means and Standard Deviations on Attitudes Toward Chemistry in Each Treatment Group by Period and by Development Stage

		Control			CAI		
Period	Stage	Mean	SD	N	Mean	SD	N
1	Non-Formal	23.428	2.637	7	23.000	4.444	9
	Formal	27.933	4.480	15	21.700	4.057	10
2	Non-Formal	23.333	3.615	6	22.222	3.768	9
	Formal	26.000	5.657	17	26.133	6.069	15

Table 12

Summary of Three-Way Analysis of Variance on Attitude Toward Chemistry

Source of Var.	Sum of Sq.	DF	Mean Sq.	F	Sign. of F
Main Effects	225.312	3	75.104	3.274	.025
Treatment	70.839	1	70.839	3.088	.083
Dev. Stage	116.152	1	116.152	5.063	.027
Hour	3.213	1	3.213	.140	.709
Two-Way Interactions					
Treatment/Stage	26.241	1	25.241	1.100	.297
Treatment/Hour	39.215	1	39.215	1.709	.197
Stage/Hour	13.809	1	13.809	.602	.440
Three-Way Interactions					
Treatmt./Stage/Hr	60.312	1	60.312	2.629	.109
Explained	409.528	7	58.504	2.550	.020
Residual	1835.370	80	22.942		
Total	2244.898	87	25.803		

Table 13

CORRELATION STUDIES

	Achievement Test	Attitude Chemistry	Attitude Computers
PSAT Math Scores	.543	.359	.185
	.000	.001	.053
PSAT Verbal Scores	.181	.243	.028
	.046	.015	.405
PSAT Index Scores	.306	.078	.078
	.002	.252	.252
Class Rank	-.656	-.300	.157
	.000	.001	.067
GPA	.664	.348	-.120
	.000	.000	.126
Score on Classroom Test of Formal Operations	.493	.197	-.124
	.000	.028	.120
- - - - - - - - - -			
Experience with computers	.101	.069	.096
	.161	.249	.179
Level of Parents' education	-.034	.028	.023
	.371	.394	.415
Ownership of a home computer	.056	.093	.122
	.292	.181	.121
Typing skill	.076	.314	.236
	.228	.001	.011
Prediction of high grade on chemistry achievement test	.650	.608	-.142
	.000	.000	.088

Note: for each combination of variables, the correlation coefficient is listed, with level of significance below it.

Appendix A

ATTITUDE SURVEY

Please respond to the following statements on your answer sheet. Your answer should reflect your own opinions or attitudes; they will have no effect on your grade whatsoever.

The following scale applies:

SA - strongly agree
A - agree
N - neutral or no opinion
D - disagree
SD - strongly disagree

	On your answer sheet, mark a	b	c	d	e
1. I think balancing chemical equations is difficult.	SA	A	N	D	SD
2. It is easy for me to learn chemistry when we use computers.	SA	A	N	D	SD
3. I've forgotten most of the things I learned while using the computer in chemistry class.	SA	A	N	D	SD
4. I would like to learn more about computers and how they can be used.	SA	A	N	D	SD
5. Chemistry is a useful course.	SA	A	N	D	SD
6. The unit on writing formulas was fun.	SA	A	N	D	SD
7. We should use computers in chemistry more often.	SA	A	N	D	SD
8. Mistakes on the computer are not as embarrassing as mistakes in class.	SA	A	N	D	SD
9. Every high school student should know how to write computer programs.	SA	A	N	D	SD
10. Chemistry is a difficult course.	SA	A	N	D	SD
11. Writing formulas is easy.	SA	A	N	D	SD
12. Doing chemistry lessons on the computer is helpful because you find out your mistakes immediately.	SA	A	N	D	SD
13. Balancing chemical equations is boring.	SA	A	N	D	SD

	a	b	c	d	e
14. All high school students should have a computer course.	SA	A	N	D	SD
15. I enjoy using computers in chemistry.	SA	A	N	D	SD
16. I would prefer doing homework assignments on paper rather than on a computer.	SA	A	N	D	SD
17. Chemistry is an interesting class.	SA	A	N	D	SD
18. Working with a computer makes me uneasy and tense.	SA	A	N	D	SD
19. Chemistry is one of my favorite classes.	SA	A	N	D	SD

Please answer the following general background questions -

20. Please rate your experience with computers, outside of this course. I have

    A. never used a computer before.

    B. used computers occasionally.

    C. a lot of computer experience.

21. The highest level of formal education achieved by either one of my parents is

    A. elementary school

    B. high school graduation

    C. vocational training or some college

    D. college or university degree

    E. graduate school or professional school

22. In my home, I have a computer which can be used for more than playing games . . .

    A. Yes

    B. No

23. My typing skills are -

    A. excellent

    B. good

    C. fair

    D. poor

24. On today's test, I think I'll probably get the following grade:

    A. A

    B. B

    C. C

    D. D

    E. F

Appendix B

Analysis of Errors on Brief Brief Test on Chemical Formulas

Category	Type of Error	
1. Totally misnamed.		
Example:	SO_3	K_2CO_3
Student Response:	sulfite	potassium carbon trioxide
Correct Answer:	sulfur trioxide	potassium carbonate
2. Confused covalent naming system with convention for ionic compounds, or vice versa.		
Example:	$Ca(NO_3)_2$	Fe_2O_3
Student Response:	calcium dinitrate	iron trioxide
Correct Answer:	calcium nitrate	iron(III) oxide
3. Spelling error in ending of formula name.		
Example:	$MgSO_4$	NH_3
Student Response:	magnesium sulfite	ammonium
Correct Answer:	magnesium sulfate	ammonia
4. Spelling errors, other than ending		
Example:	$AlCl_3$	CuS
Student Response:	alumminum cloride	cuper(II) sulfide
Correct Answer:	aluminum chloride	copper(II) sulfide
5. Wrong name or wrong charge used.		
Example:	K_2CO_3	Fe_2O_3
Student Response:	potassium percarbonate	iron (II) oxide
Correct Answer:	potassium carbonate	iron (III) oxide
6. Total Error in writing formula.		
Example:	potassium acetate	ferric iodide
Student Response:	K	I_6
Correct Answer:	$KC_2H_3O_2$	FeI_3

7. Error in prefix, symbols or polyatomic ions in writing formula.

Example:	carbon tetrachloride	potassium acetate
Student Response:	CCl_5	$KH_2C_3O_2$
Correct Answer:	CCl_4	$KC_2H_3O_2$

8. Use of wrong charge or reversed subscripts in writing formula.

Example:	magnesium bromide	sodium oxide
Student Response:	$MgBr$	NaO_2
Correct Answer:	$MgBr_2$	Na_2O

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